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MINERAL RECOVERY FROM THE NONCOMBUSTIBLE FRACTION OF MUNICIPAL SOLID WASTE

A PROPOSED PROJECT TO DEMONSTRATE INCINERATOR RESIDUE RECOVERY

ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C.

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a current report on solid waste management

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MINERAL RECOVERY FROM THE NONCOMBUSTIBLE FRACTION OF MUNICIPAL SOLID WASTE

A Proposed Project To Demonstrate Incinerator Residue Recovery

This report (SW-82d.1) was written
by DAVID G. ARELLA and YVONNE M. GARBE
on work performed under Federal solid
waste management demonstration grant No. S-801535
that was awarded to the City of Lowell, Massachusetts,
in October 1972, and cancelled at the request of the
grantee in July 1975.

U.S. ENVIRONMENTAL PROTECTION AGENCY

1975

FOREWORD

In July 1975, shortly after this report was written, steps were initiated to cancel a grant that had been awarded to the City of Lowell, Massachusetts, to demonstrate mineral recovery from incinerator residue. The decision to cancel the grant resulted primarily from two unresolvable problems, which did not include the technical or economic viability of the recovery process itself.

First, the City of Lowell was obligated to upgrade its incinerator in order to conform with Federal air pollution standards, as well as to meet the requirements of the grant. These upgrading costs were estimated at more than $5 million, far more than originally anticipated. This amount exceeded both the original cost of the incinerator and the cost of the resource recovery facility and, therefore, was considered prohibitive.

Second, there was insufficient incinerator residue to process in the resource recovery plant. Originally, the Lowell incinerator would have provided half the volume of residue needed to operate the plant one full 8-hour shift. Additional residue from incinerators operating in nearby communities would have been brought in to supplement the volume. Unfortunately, in 1973 and 1974, several of these communities closed their incinerators because of noncompliance with Federal air pollution standards, thus, creating the problem of insufficient residue volume.

There was another, less significant, cost increase in the project. The estimated cost of the proposed resource recovery plant increased by $2.034 million from 1972 to 1975, due to inflation and modifications of the plant design. These increased costs are reflected in the economic analysis of the project in this report, and it should be noted that, in spite of these increases, the process remains economically attractive.

The grant cancellation should not be interpreted as a change in EPA or Lowell attitude about the economic or technical feasibility of the incinerator residue recovery system.

This report is published to document the valuable work completed on this project before termination.

—SHELDON MEYERS
Deputy Assistant Administrator
for Solid Waste Management

MINERAL RECOVERY FROM THE NONCOMBUSTIBLE FRACTION OF MUNICIPAL SOLID WASTES

Concern for environmental quality has grown dramatically in recent years, and solid waste management has attracted particular attention for three reasons.

First, we now realize that our discards contain significant quantities of valuable materials. Reuse of these materials can make significant contributions towards reducing the drain of our natural resources, forestalling material shortages, and improving the Nation's material trade balance.

Secondly, recent studies by the U.S. Environmental Protection Agency (EPA) indicate that manufacturing processes which use recycled materials, instead of virgin materials, generally produce less air and water pollution and require less energy. With rising energy costs and increasingly stringent environmental regulations, the use of recycled materials may soon be cheaper in many cases than the use of virgin materials.

Finally, we have begun to understand more clearly the necessity to protect our lands and waterways from improper waste disposal techniques. Evolving environmental regulations will improve the quality of our solid waste disposal activities; the cheap, open burning dump will be outlawed, but the costs of handling our wastes satisfactorily will increase accordingly.

The concept of recovering resources from our wastes was spawned by these factors and, in fact, offers a partial solution to all three. Solid waste management systems which recover resources can reduce material and energy shortages as well as offer a means of disposal which is both cost competitive and environmentally satisfactory.

Therefore, the challenge is to develop technically and economically viable systems for extracting resources from our wastes and reintroducing them into the production cycle. The Solid Waste Disposal Act as amended (Public Law 91-512) is evidence of this maturation in our materials use policies. This act authorizes the Federal Government to aid in the development and demonstration of systems which would recover material and energy resources from solid wastes. Demonstrations of technology are supported by Federal funds which absorb most of the risks in implementing prototype plants. The payoff for the demonstration grant program is a duplication of these concepts, once demonstrated to be technically and economically feasible, in other locations without further Federal financial participation. Demonstration grants have proven to be effective tools for stimulating the implementation of new technologies. This report describes one of the projects that had been selected for funding, although under this Act it has since been cancelled (see Foreword): the recovery of minerals from the noncombustible fraction of solid wastes.

The original concepts were developed and pilot-tested by the U.S. Bureau of Mines (USBM). This work was the basis for an application from the City of Lowell, Massachusetts, to demonstrate a system for recovering iron, aluminum, copper, and glass from the residues left after incineration of municipal solid waste. The project included the design, construction, and evaluation of a large system to handle 250 tons per 8 hours a day of incinerator residue. The project was to be implemented in order to hasten the advancement of resource recovery by shortening the gap between research and full-scale implementation. Cost escalations and the need to upgrade the incinerator to meet air pollution regulations led to the cancellation of the project.

Project Objectives

The first objective of this project was to demonstrate the technical and economic feasibility of a mechanical system for recovering metal and glass from the noncombustible portion of solid wastes. Standard mineral beneficiation techniques and off-the-shelf equipment were used in a novel arrangement to separate and recover salable materials. The primary products would be ferrous metal, aluminum, a copper-zinc composite, sand, and a clean, mixed-color glass fraction suitable for recycling. These materials can be recovered from incinerator residues, but the system was also designed to handle noncombustible solid wastes that have been separated from the combustible fraction by air classification or by some other means. The ability to handle the noncombustible fraction from both incinerated and non-incinerated solid wastes gives this system wide application as one of the building blocks in future resource recovery systems.

A second objective of this project was to evaluate the quality, marketability, and potential uses for materials recovered from solid waste. The project would attempt to identify the major constraints to recycling and to demonstrate an effective marketing approach which depends on maximum communication between the solid waste processor and the secondary materials buyer.

A third objective was to demonstrate the value and viability of a regional approach to resource recovery systems. Before the grant was cancelled, the Lowell incinerator facility was processing solid waste from two communities besides Lowell, and the resource recovery system would rely on a supply of incinerator residue from several additional communities. As a result, the State of Massachusetts, in developing their statewide resource recovery program, intended to use this resource recovery facility as one of its major processing points for noncombustibles.

Participants and Their Roles

This project involved a unique cooperative venture involving the local, State, and Federal Governments. The U.S. Environmental Protection Agency awarded approximately $2.4 million to the City of Lowell to support 46 percent of the total estimated project cost of $4.4 million. The State of Massachusetts agreed to provide $615,000, and the remainder was to be provided by the City of Lowell.

The system designer for the project is the Raytheon Service Company of Burlington, Mass. Significant consultation has also been provided by the U.S. Bureau of Mines personnel who pioneered the early development of the system. The USBM pilot plant at Edmonston, Md., has been used under a cooperative agreement with Raytheon to perform additional pilot plant testing that resulted in further system refinements.

At the time of cancellation, the design phase of the project had been completed, and the construction phase had advanced to the point where bids had been released for the construction of the resource recovery facility. The reader should be aware that much of the information presented here, especially that which concerns recovery rates and economics, is preliminary and is subject to further verification. The numbers used to describe recovery rates and percentages are based on studies at the USBM pilot plant.

SYSTEM DESCRIPTION

Original Developmental Work by USBM

The original developmental efforts on this system were conducted by the U.S. Bureau of Mines. USBM involvement stemmed from its work in the mining industry. It was perceived that incinerator residues might be viewed as a mineral-rich "urban ore" which could be subjected to and separated by the same mineral separation and beneficiation techniques which have been used in the mining industry for many years.

The USBM began the early development work on this concept in 1966. This work culminated in the construction of a small pilot system at its Edmonston, Md., facility. Completed in 1970, this pilot system has a throughput capacity of 1,000 pounds per hour. Since then, the Bureau has continued to perform numerous tests on incinerator residues from all over the country. Results from these pilot tests were used to improve the system design and operation.

During the detailed design of the Lowell facility, Raytheon Service Company performed additional analysis on USBM historical data and, in conjunction with USBM personnel, ran extensive additional pilot-plant test runs on Lowell residue. As a result of this additional work, the system design differs in some aspects from the data published by USBM on the system. Raytheon Service Company has continued to seek consultation from USBM staff, and due to this extensive pilot-level work, the project staff has a high degree of confidence in the technical feasibility of the final plant.

Overall Design Approach

Unlike EPA's other resource recovery projects, this process will not handle the entire solid waste stream. It is, rather, a subsystem, within a total resource recovery/disposal system, for extracting the mineral values from the noncombustible fraction of the solid waste stream.

The system was designed to accept a very heterogeneous input material and produce a series of basic metal alloys and glass which are suitable for recycling into existing material markets. High purity and consistency of the output products have been important design objectives in order to achieve maximum price and marketability.

In addition to the previous USBM pilot work, substantial preliminary discussions with the expected buyers of the output materials were a major factor in preparing the final design. Sample products from the pilot tests were distributed to potential buyers for scrutiny, analysis, and recommendations. Their responses were important in determining how to maximize the marketability of the various products. These responses were also used in preparing the final design to match as closely as possible the material specifications of the probable buyers. EPA recommends this approach to designing any resource recovery system. It is worth emulating.

Finally, the design development was also supplemented by a large number of tests performed on the anticipated full-scale equipment units to verify the ability of large commercial-scale equipment to duplicate the pilot plant results. In fact, nearly every processing step was tested on full-scale units, on a piecemeal basis, using residue from the Lowell incinerator. Proven equipment, available from the mineral beneficiation field, is utilized in the process in order to reduce risks in development. Evaluating the effectiveness of this equipment for processing solid waste would have been a major objective of the demonstration project.

Description of Process Flow

The following is a functional description of the process operation as presently conceived (Figure 1).

Primary sorting. Incinerator residue is pushed off a tipping floor onto a vibrating conveyor by a front-end loader. The vibrating conveyor evens out the flow of material and feeds in uniformly into the trommel which is a rotating cylindrical screen with 1 1/4-inch holes. The trommel separates the residue into a metal-rich fraction greater than 1 1/4 inch and a glass-rich fraction which is less than 1 1/4 inch.

Ferrous separation. The trommel oversize, which makes up about 20 percent of the incoming residue, is fed to the ferrous separation section of the plant. It is first conveyed past a hand-picking station where massive metals may be removed from the material along with some nonferrous metals of particularly high value. This step protects the shredder from damage. After the picking station, the trommel oversize stream is fed to the primary shredder, and the ferrous metals are removed by a drum magnet.

The recovered magnetic fraction, 80 percent of which is light ferrous scrap, such as cans, has a density of about 22 pounds per cubic foot and, on melting, has a metal yield of about 85 percent. Most steel mills require densities of 75 pounds per cubic foot and a yield of 88 percent purity. Therefore, although not shown on the flow sheet, an additional cleanup and densification step is required. A ring grinder will be used for this densification step. This secondary shredding of the metal fraction produces small dense particles, 3/4-inch in diameter. This product is then separated from the slag and oxides knocked off in the shredder by washing followed by a secondary magnetic separation step.

The trommel undersize, which makes up about 80 percent of incoming residue, consists mostly of glass, but contains some ferrous and nonferrous metals along with paper, unburned organics, and ash. A coarse material washer is used to wash out much of the ash and unburned material. Another drum magnet separates the smaller iron particles, which join the balance of the ferrous product recovered from the trommel oversize.

Copper-zinc separation. The nonmagnetic material discharged from the organic material separator is fed through a surge hopper/feeder into a density separation device called a jig which performs two functions. First, it performs a second-stage cleanup for removal of unburned organics, ash, and other light waste. Second, it removes heavy nonferrous metals, such as copper and zinc, from the residue. The remaining light nonferrous metals (e.g., aluminum) and the glass fraction, which now have been separated from the heavy nonferrous metals, iron, ash, and unburned material, are conveyed into a large surge hopper.

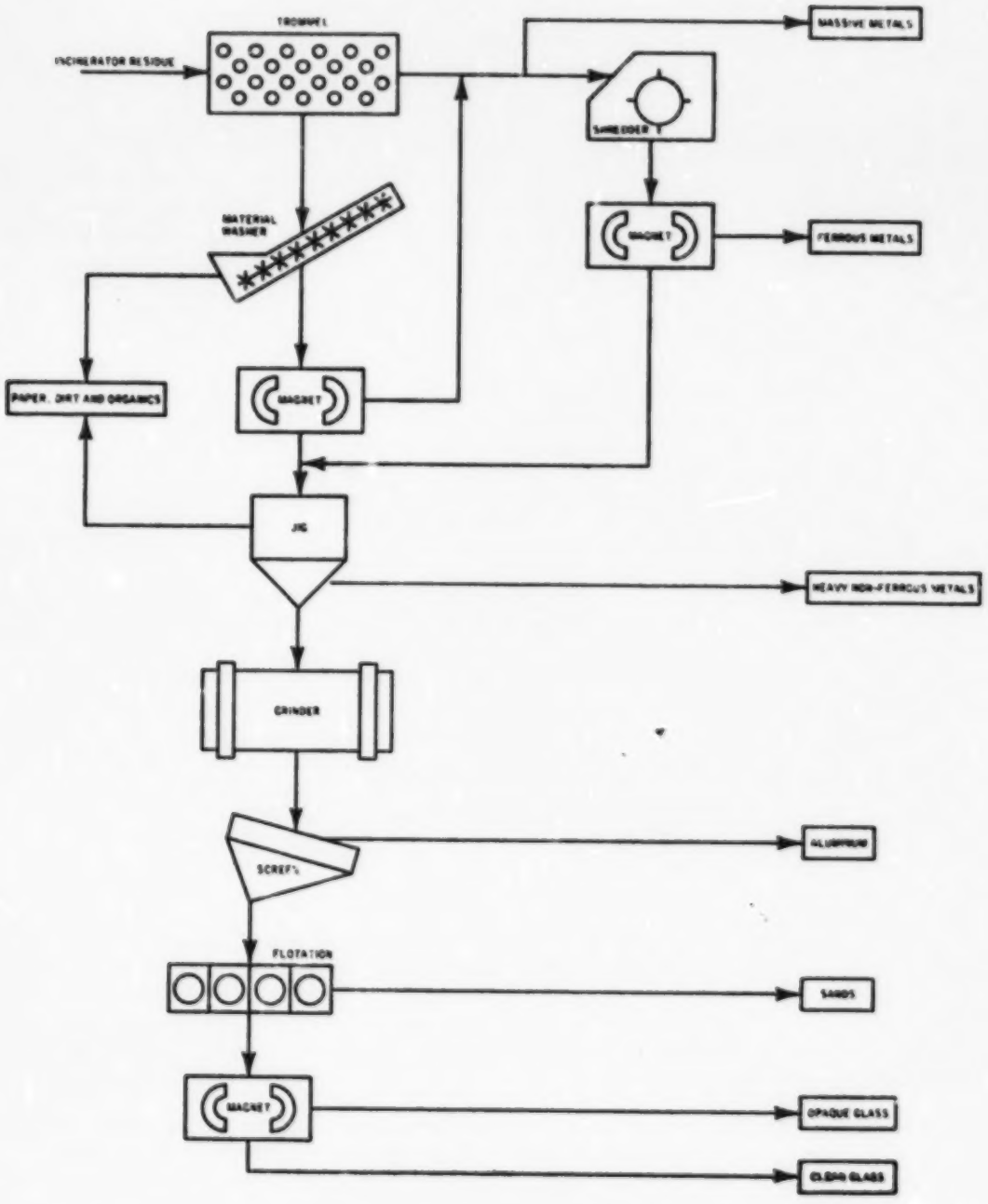

Figure 1. This simplified flowsheet indicates the seven basic operations used for processing the incinerator residue: primary sorting, ferrous separation, copper-zinc separation, buffer storage, aluminum separation, glass separation and cleaning, and water treatment.

Buffer storage. A large surge hopper (not shown on the flow sheet) is provided in the center of the system to allow uniform feeding of the second half of the plant and to permit production of output products during short shutdown periods occurring in the first half of the processing plant. The first part of the plant processes an extremely heterogeneous random material; it will require considerable maintenance during operation. To compensate for this, this section of the plant has been designed to handle approximately twice the average processing capacity. The second half of the plant which treats a fairly uniform type of material is designed with closer tolerances and is expected to run smoothly with few breakdowns and maintenance problems.

Aluminum separation. Material discharged from the large surge hopper consists primarily of glass and aluminum. This material is processed in a series of crushing and screening steps. The theory of operations in this section is that glass and other friable materials will be crushed to very small particle sizes while the pieces of aluminum which are malleable will instead be flattened out by the crushing action. Subsequent screening can then perform an easy size-separation for recovering the aluminum.

Glass separation and cleanup. The glass-rich fraction leaving the crushers has very small particle sizes. This fraction is fed to a froth flotation cell which removes slag, brick, ceramic, and stone and produces a clean glass product. The flotation rejects are dewatered and recovered as a sand product. The recovered glass is dried and then separated into two fractions by a high intensity magnetic separator. One fraction is a clean mixed-color glass product suitable for making bottles. The other fraction is basically glass which has been contaminated by iron during incineration. This material is not suitable for making new bottles and will probably be included in the sand product.

Water treatment. Most of the processing is carried out in the presence of water. Water is collected from several sumps throughout the process. Suspended solids are removed by means of sedimentation. These solids are pumped to a vacuum drum filter and make up the filter cake material which is planned for land disposal. Clean water is recycled.

The quantity of water used for processing incinerator residue is about 2200 gallons per ton of residue on a dry weight basis. By recycling most of this water about 6 times through the plant, the make-up water required is only about 360 gallons per ton of residue.

PRODUCT DESCRIPTION--MARKETING

Ferrous Metals

Physical description. This product, called incinerated ferrous scrap, consists mostly of light ferrous metals such as tin cans, nails, and bottle caps along with some smaller pieces of ferrous metal. Particles are generally spherical in shape and range in size from 1/4 to 1 inch. This material, packed loosely in a container, has a density of about 75 pounds per cubic foot.

Quality discussion. The material is somewhat rusted. Most of the food matter, labels, and coatings have been burned off during incineration. This product is generally not suitable for detinning because a substantial part of the tin coating on the cans has been removed or diffused into the iron during incineration, thus making detinning uneconomical. This material should have about a 93 percent ferrous metal yield.

Market potential. This ferrous scrap can be used by small steel mills (mini-mills), ferrosilicon producers, and by scrap export dealers. If the ferrous scrap were prepared differently, it would also be suitable for the precipitation of copper from low-grade copper ores. "Nuggetizing" the metal makes it unsuitable for copper precipitation, but enhances its value for steel production. Usually, mini-mills and ferrosilicon producers will dilute this material with other ferrous scrap in order to reduce the copper and tin contaminations to acceptable levels for their use. Mill prices for incinerated ferrous scrap varied from $10 to $45 per ton in the 1972 to 1974 period. If the scrap is channeled through a scrap dealer, the seller would receive a somewhat lower price.

Preliminary buyer response. In March 1975, the incinerated ferrous scrap was valued at $22.50 per ton for use in a steel mill.

Aluminum

Physical description. The aluminum scrap product is a nugget-like mixture of aluminum alloys. This material is screened to recover nuggets ranging from .14 to 4 inches. As a result of incineration, the aluminum melts into a dense globular form which has a density of 91 pounds per cubic foot.

Quality description. This is a very high-quality aluminum product. The coarse nuggets are fairly pure aluminum alloys that contain very little, if any, paint, labels, or other contaminants. Furthermore, the product is not heavily oxidized and has a yield on melting of over 72 percent. Actual yields from residue processed in the pilot plant very often have exceeded 85 percent. The 72 percent yield is acceptable to aluminum processors and should be readily obtained by the plant.

Market potential. The aluminum scrap can be used for remelting by secondary aluminum ingot suppliers and by primary producers who process scrap into higher grade ingots for foundries and other specialty users. Prices for scrap, similar to this, varied from $160 to $360 per ton in the 1972 to 1974 period.

Preliminary buyer response. Samples of the expected aluminum scrap product were circulated to three or four secondary aluminum processors. In March 1975, their quotes for this product ranged from $250 per ton delivered to the processor.

Heavy Nonferrous Metals (Copper-Zinc Composite)

Physical description. The copper-zinc scrap product is a mixture of nugget-like nonmagnetic metal alloys consisting mostly of copper-base and zinc-base alloys. Samples may also contain some nonmagnetic stainless steel and very small quantities of precious metals. The particles are between .14 and 4 inches. The material has a density of 180 pounds per cubic foot.

Quality discussion. This product is roughly 60 percent copper base, 30 percent zinc base, and 10 percent other nonmagnetic metals. This material has no nonmetallic contaminants, and the various components can be readily separated and recovered through conventional processes in the secondary metals industry.

Market potential. Mixed copper and zinc-base alloys can be used by major copper refiners who extract the copper value. Prices for this product varied from $300 to $867 per ton between 1972 and 1975.

Preliminary buyer response. The price quoted by one of the copper smelters in New Jersey in March 1975, was $330 per ton delivered.

Mixed-Color Glass

Physical description. This product is a finely ground, carefully cleaned mixture of non-color-sorted glass, resembling yellow-white beach sand. When melted in a 100-percent mix, this material has a light amber or emerald green color. The material is dry and has a density of 75 pounds per cubic foot.

Quality discussion. This product has been froth-floated to remove ceramics and stones. Glass test melts are transparent and have been free of stones, seeds, or similar defects.

Consideration was given to color-sorting, which would increase the market value. However, currently available color-sorting equipment requires much larger particle sizes (1/4 in. to 3/4 in.), and since local markets exist for the mixed-color glass product, color-sorting was not selected.

Market potential. The market potential for a non-color-sorted glass product is significantly limited vis-a-vis color-sorted cullet. However, clean mixed-color glass can apparently be used with virgin materials (silica sand and soda ash) at proportions of 5 to 15 percent in making flint bottles and perhaps as high as 50 percent in making green or amber bottles without causing significant changes in the color of the bottle. Prices for this product varied from $10 to $25 per ton during 1972 to 1975.

Preliminary buyer response. The Glass Container Corporation plant in Dayville, Conn., and/or the new Owens-Illinois plant in Mansfield, Mass., quoted a price of $22.50 per ton for mixed-color glass in March 1975.

"Sand"

Physical description. The "sand" product resembles dark beach sand. It is composed of fine ceramic, brick, stone, slag, and other friable materials including glass. This product may also contain some metals too fine to be recovered. The density of this material is 70 pounds per cubic foot.

Quality discussion. Work is in progress to evaluate this product as a road-surfacing material to be mixed with coarse aggregate and to be used in asphalt or concrete-paving mixtures. As a fine aggregate, this product might have a value of about $2 per ton.

ECONOMICS

In Proper Perspective

The economic information that follows is based on significant pilot plant experience and engineering estimates. The economics are sensitive to capital costs, operating costs, product yields, and prices for the recovered materials. An attempt has been made here to present current expectations which are neither optimistic nor pessimistic. An evaluation of the economics of this plant would have been a major objective of the demonstration plant. Finally, the economic analysis presented here reflects numerous conditions specific to the Lowell area, and, therefore, costs or revenues could vary significantly if the plant were located elsewhere.

Projected Economics

The economic data indicate that the capital cost for this particular recovery plant is estimated to be $4.12 million (Table 1).

TABLE 1

CAPITAL COSTS*

Design, Construction Management, Shakedown	$798,000
Equipment & Construction	$3,321,000
TOTAL	$4,119,000

*Capital costs are based on 1975 estimates and quotes at Lowell, Massachusetts, and do not include cost for land.

The projected operating costs and revenues show that for a 1-shift-per-day operation the plant will cost $36,000 per year, or about $0.55 per ton of input residue (Tables 2 and 3). If the plant were operated on 3 shifts, the projected profit would be about $990,000 per year, or $5.05 per ton of input residue.

Discussion of Economics

The economic viability of an incinerator residue recovery system is a function of recovery rates, throughput capacity, economic life span of the hardware, operating costs, and market prices for the products. The revenues derived from the sale of the recovered products are expected to almost equal the costs of construction and operation. An increase in revenue would result in additional profit which can be used to reduce overall disposal or resource recovery system costs. Since incinerator residues normally require landfilling, which is becoming increasingly expensive, this resource recovery system may reduce the landfill volume requirements by 70 percent or more and thereby provide the overall solid waste management system with additional savings.

TABLE 2

ESTIMATED REVENUES*

	Percent Recovery (dry weight basis)	Value $/Ton	Revenue $/Ton Input Residue
Aluminum	1.25	250	$3.12
Copper/Zinc	.63	330	2.08
Ferrous	14.6	32.90	4.80
Clean Glass	30.0	22.50	6.75
Sand	24.17	2.00	.50
Filter Cake	15.6	0	0
Organics	13.75	0	0
TOTALS	100.00		$17.25

*Based on material values quoted by interested secondary materials buyers in March 1975. Aluminum and copper-zinc values are F.O.B. the resource recovery plant. Haul costs for the remaining materials are not included in the above quoted values. However, hauling costs have been included in the operating cost estimates presented in Table 3.

TABLE 3

PROJECTED OPERATING ECONOMICS

	1 Shift/Day (250 tons of residue per 8-hour-day, 260 days-per-year, 65,000 tons processed per year)		3 Shifts/Day (750 tons of residue per 24-hour-day, 260 days-per-year, 195,000 tons processed per year)	
	Cost (Income) per year	Cost (Profit) per ton input	Cost (Income) per year	Cost (Profit) per ton input
Capital Cost*	$424,000	$6.50	424,000	$2.20
Operation and Maintenance**	$734,000	$11.30	$1,950,000	$10.00
TOTAL COST	$1,158,000	$17.80	$2,374,000	$12.20
Revenue***	($1,122,000)	($17.25)	($3,364,000)	($17.25)
Net Cost (Profit)	$36,000	$0.55	($990,000)	($5.05)

*Capital Costs are amortized using an economic life span of 15 years and a 6 percent interest rate.

**Operating and maintenance costs are based on 11 to 12 persons/shift at an average salary of $10,000 per year.

*** Revenue estimates are based on March 1975 material values.

ENVIRONMENTAL CONSIDERATIONS

An environmental impact appraisal was prepared for this project. The appraisal concluded that the potential environmental impact of this project is not considered to be significant. The areas of possible detriment can be monitored and controlled adequately to eliminate any environmental pollution. However, the anticipated benefits are significant. Pollution resulting from improper land disposal will be reduced, while natural resources are conserved.

Land

This system will reduce the landfill volume requirements for incinerator residues by over 70 percent. Initially, the unburned organic material in the residue and the filter cake will be disposed of in Lowell's sanitary landfill. At a later time, the organic fraction will be reintroduced into the incinerator for disposal, and the landfill volume requirements will thereby be reduced by over 85 percent.

The filter cake has the appearance of fly ash from an incinerator. It consists of suspended solids removed from the processing water and is mostly ash and dirt contained in the incoming residue and some fine glass produced during crushing and grinding. Initially, this material will be landfilled; however, alternative uses for this product as a fill material replacing soil are currently under investigation.

Air

The process employs primarily wet-processing techniques; therefore, there will be a minimum dust problem. However, a dryer is used in the glass cleanup section and the exhaust gases from the drier will be cleaned in a small bag house.

Water

The plant would require about 50,000 to 100,000 gallons per day of make-up water. About 270,000 gallons per day would be treated and reused in the plant. A water treatment system would be incorporated at the plant to treat 885,000 gallons of process water per day. The plant would use a 10 to 1 recycle ratio and would discharge approximately 100,000 gallons per day of properly pre-treated and fully acceptable effluent to a municipal sewer system. This effluent can be readily handled by a city's waste water treatment plant.

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